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Atmospheric Infrared Sounder

Improvements For V6 To Handle Channel Frequency Shifts

Denis Elliott

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Introduction

- **In this talk I will describe work in progress to enable V6 to account for the small, time-dependent frequency shifts of the AIRS IR channels**
  - ***The existing L1B algorithm to measure the shifts will be improved***
  - ***The dynamic frequencies will be used in Level 2***
  - ***A Level 1C product will be generated which will consist of cleaned-up spectra optionally resampled onto a fixed frequency grid***
- **Many people are contributing to this effort, including:**
  - ***George Aumann***
  - ***Yibo Jiang***
  - ***Evan Manning***
  - ***Margie Weiler***
  - ***Larrabee Strow***
  - ***Scott Hannon***

Outline

- The need for better handling of frequency shifts
- Requirements for V6
- Preliminary design and algorithm descriptions
  - *The four components of the shifts*
  - *Dynamic determination of frequency shifts*
  - *Noisy channels detection and monitoring*
  - *Cleaning up noisy spectra*
  - *Shifting to a fixed frequency grid*
- Summary of planned software changes

Why do we need to handle the extremely small frequency shifts?

- We have always known that AIRS channel frequencies vary slightly with time, due primarily to small changes in temperature gradients in the spectrometer
- Using a fixed frequency set in L2 works fine for meeting our 1K / 1 km primary requirement, weather prediction, and many other purposes
- For climate studies, where we want to measure trends at the 10 mK/yr level, we need to properly account for the shifts in both L1 and L2
  - *Existing L1B code attempts to measure the shifts, but the results are noisy and V5 makes no use of the results*
- Thus we have three new top-level requirements for V6
  - *Measure frequency shifts as accurately as we can*
  - *Provide a prescription (and possibly a product) for resampling radiances to a truly fixed frequency grid (Level 1C)*
  - *Account for the dynamic frequency shifts during retrievals*

Detailed Requirements (1 of 2)

- **L1B—**
  - ***Determine and record instantaneous frequencies of all channels***
  - ***Provide a list of noisy channels for use in Level 1C***
- **L2—Modify the RTA to make use of the actual frequencies that were determined in L1B**

Detailed Requirements (2 of 2)

- L1C—(new)
  - Define a set of fixed channel frequencies, including pseudo-channels to fill gaps in existing spectral coverage
  - Generate (or provide prescription for) Level 1C products
    - "Clean" product
      - Replace radiances of noisy channels and supply radiances of pseudo channels using best available radiances from correlated good channels
      - Do not disturb L1B radiances of good channels
      - Supply information specifying whether radiance is NIST traceable (good channels) or not (noisy and pseudo channels)
    - Resampled product
      - Resample the "clean" spectra onto the fixed frequency grid

Possible L1C Output Options

- **Just provide a routine for users to generate their own "clean" and (optionally) resampled spectra**
- **Have Level 1C products ("clean" and/or resampled) produced at the GES DISC, but only by request for user-specified granules**
- **Routinely output a full Level 1C product (cleaned and resampled calibrated radiances)**

Frequency shifts and their dynamic determination

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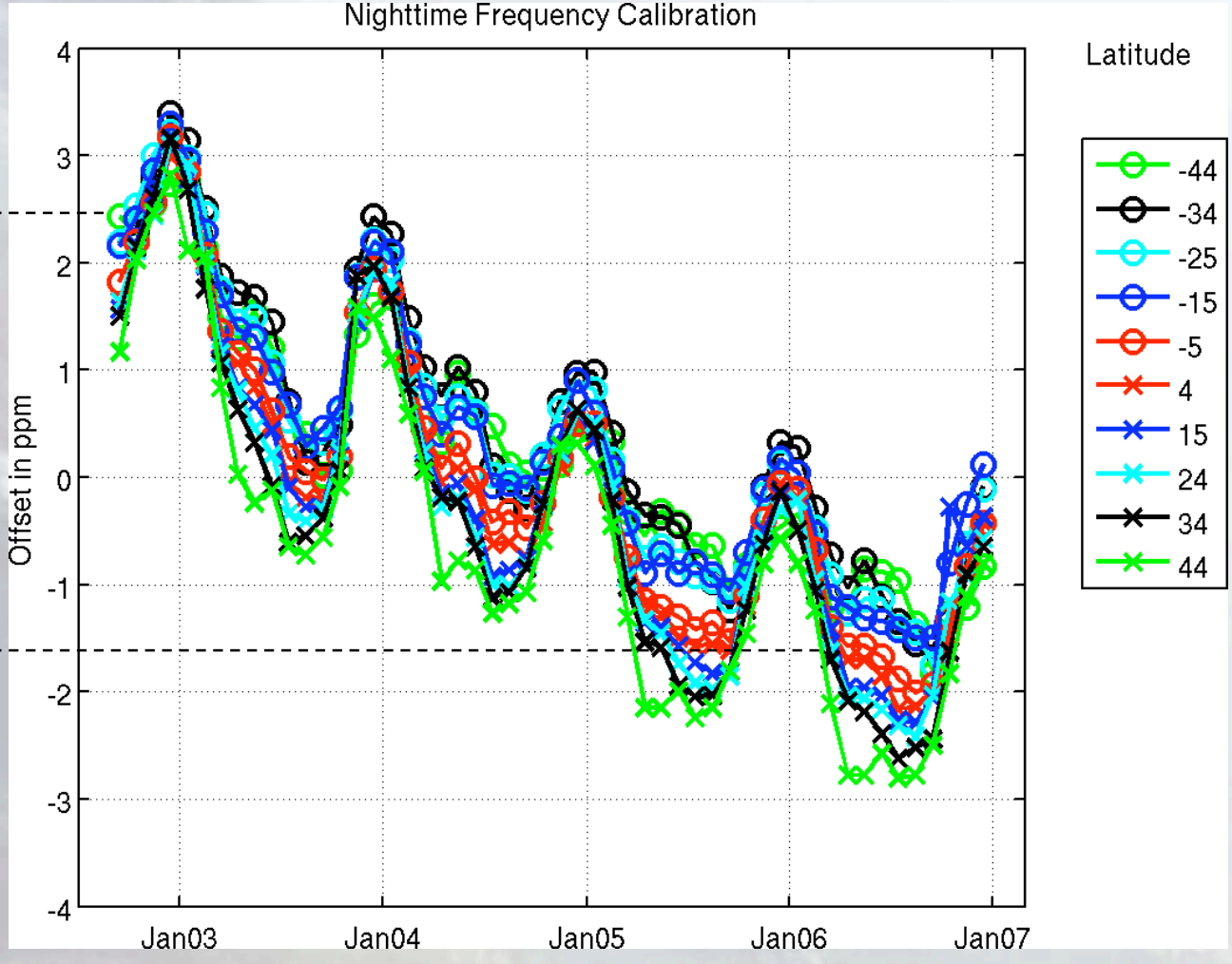
Observed Frequency Shifts

< 1 ppmf/yr



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Frequency Shifts

- **Results from CO_2 and H_2O channels are very similar which implies that all the detector modules are shifting together**
- **Latitude is used in the previous chart as a rough proxy for orbital position**
  - ***At least two methods for predicting the orbital shift are being investigated***
    1) Using time and orbital phase information to determine the time since entrance into or exit from the earth's shadow
    2) Using the current of the choke point heater, which tries to maintain the spectrometer at constant temperature by controlling a heater on the second stage radiator
- **Strow and Hannon showed that the seasonal oscillation with peak-to-peak amplitude 3 ppmf tracks the solar beta angle**
- **There is a secular change of approximately 1 ppmf/yr**
- **There is also 24-hour cycle in spectrometer temperatures which is captured by the choke point heater current**

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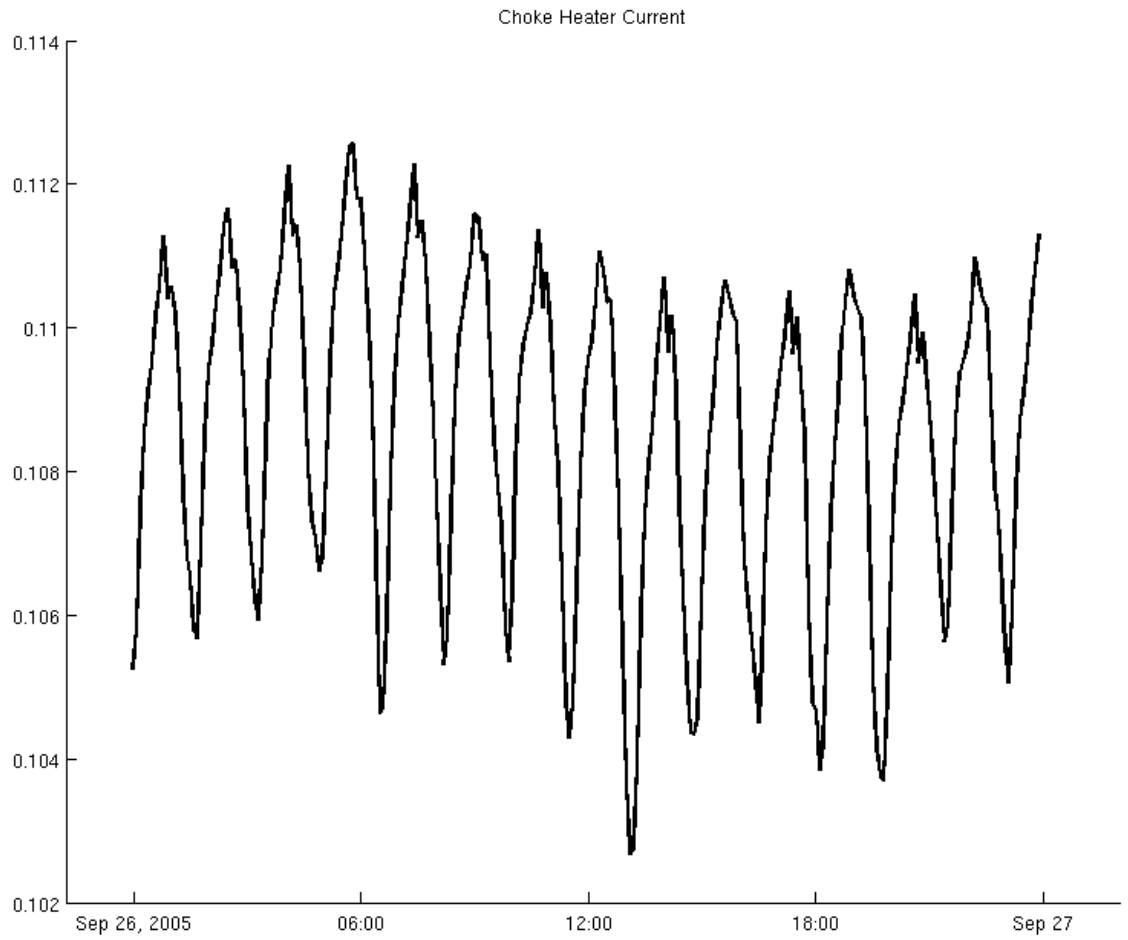
Choke Point Heater Current Typical Day



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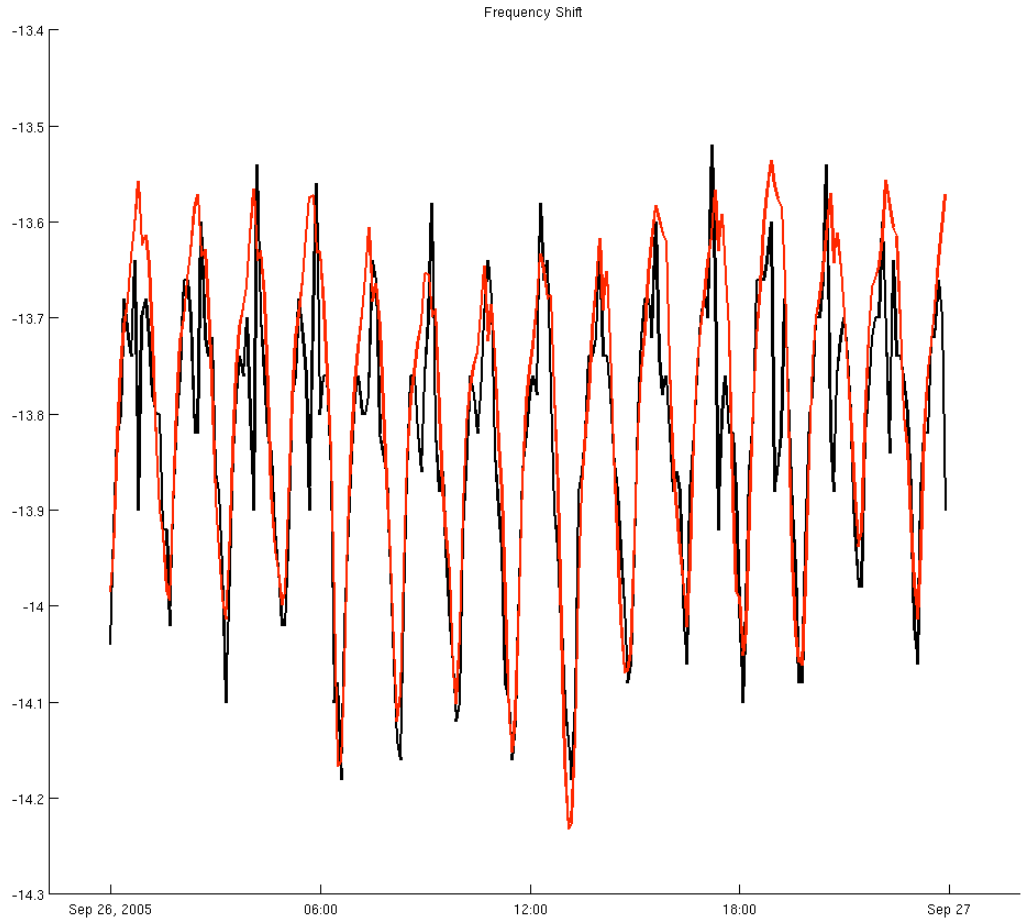
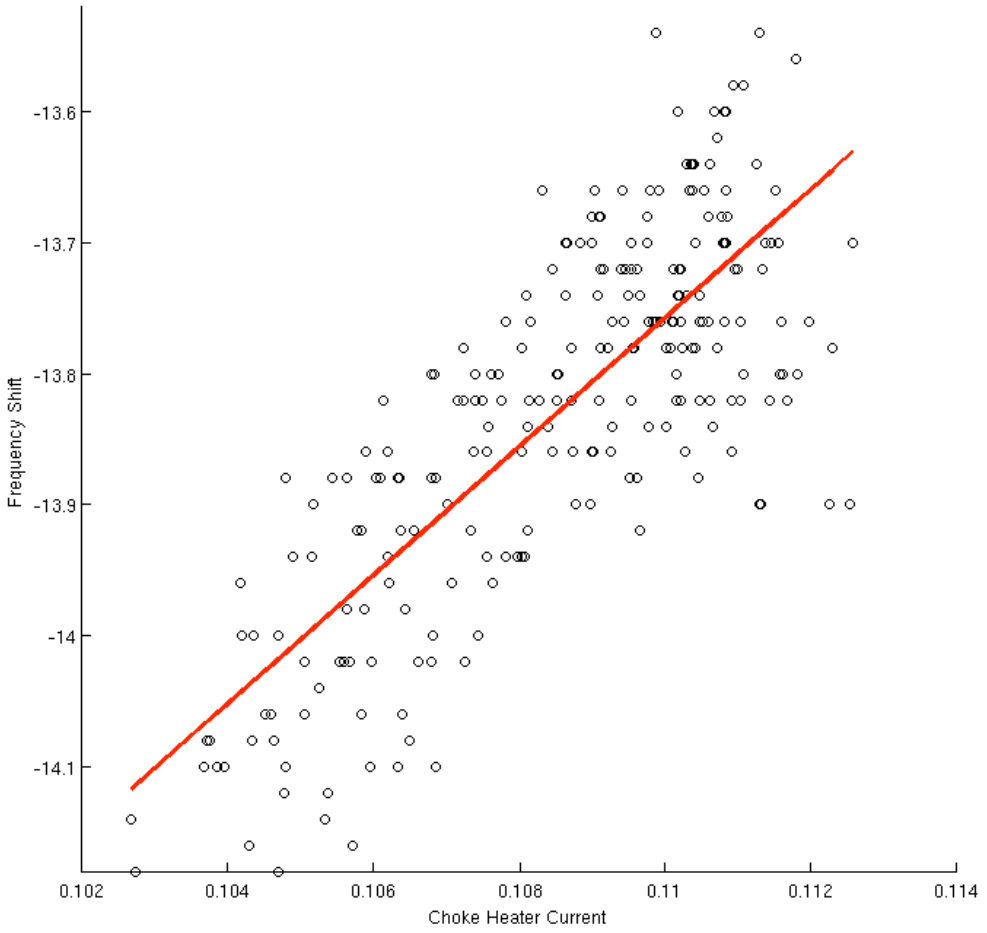
Frequency Shift (Actual and Predicted)

- **Black—Actual (measured by Hannon)**
- **Red—Predicted (from observed choke point heater current)**



Heater Current vs. Frequency Shift

- **Correlation coefficient is 0.78**



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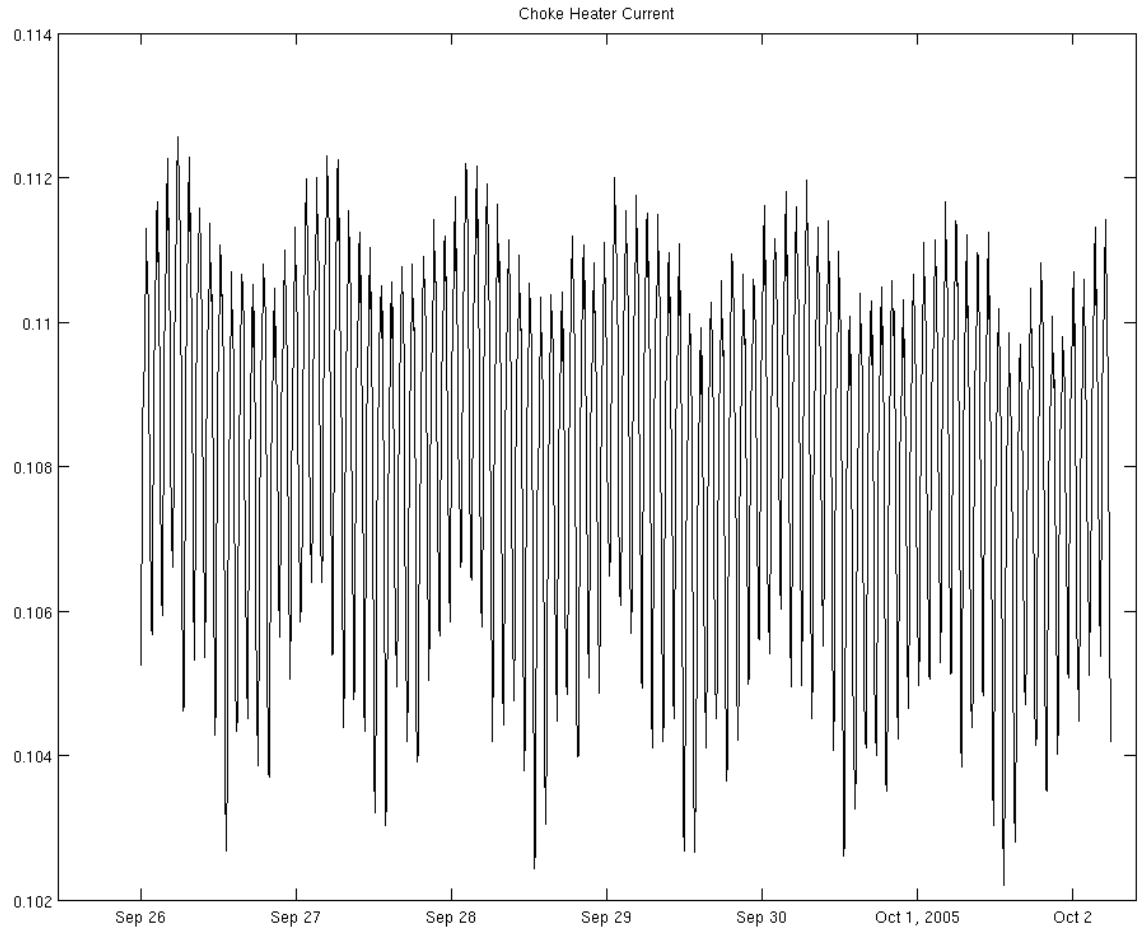
Daily Cycle As Seen In Choke Heater Current



Dynamic Frequency Determination

- **The instantaneous frequencies can be determined from three or four predictors known at run time**
  - ***Orbital component***
    - Choke point heater current or
    - Time since terminator crossing
  - ***Daily component***
    - Choke point heater current or
    - UTC
  - ***Seasonal component***
    - Solar beta angle
  - ***Secular component***
    - Date

Detection and Monitoring of Noisy Channels

Noisy Channel Detection Using PCA

- **Once per mission, train on a set of 48 simulated AIRS clear spectra**
- **At a TBD frequency, use a test spectrum (actually observed) determined to be clear from a sea surface temperature comparison test**
  - ***Use principal component analysis to calculate a reconstructed spectrum from the test spectrum***
  - ***Analyze the brightness temperature difference between the raw test spectrum and the reconstructed***
    - Mark a channel "replaceable" if the difference is large (> 10K) or if the difference divided by (1 + NEΔT) exceeds 5
  - ***Generate a known "replaceable" channels list by concatenating the list of channels declared dead before launch to ones found to be bad by the PCA analysis***

Replacement Of Noisy Channel Radiances

Radiance Replacement ("Clean")

- The goal of spectrum clean-up (radiance replacement) is to permit interpolation and resampling without fear of introducing artifacts
- For each AIRS IR channel, a list of up to 10 possible replacement channels has been determined
  - *A channel can replace another channel if their brightness temperatures are expected to be close AND*
  - *If the channels are both window channels or both water channels or both ozone (etc.) AND*
  - *If the channels are close in frequency*
- For each spectrum, for each channel on the "replaceable" list, set the radiance to a TBD combination of channels from its replacement set
- This "cleaning" process will not disturb radiances of channels not marked for replacement

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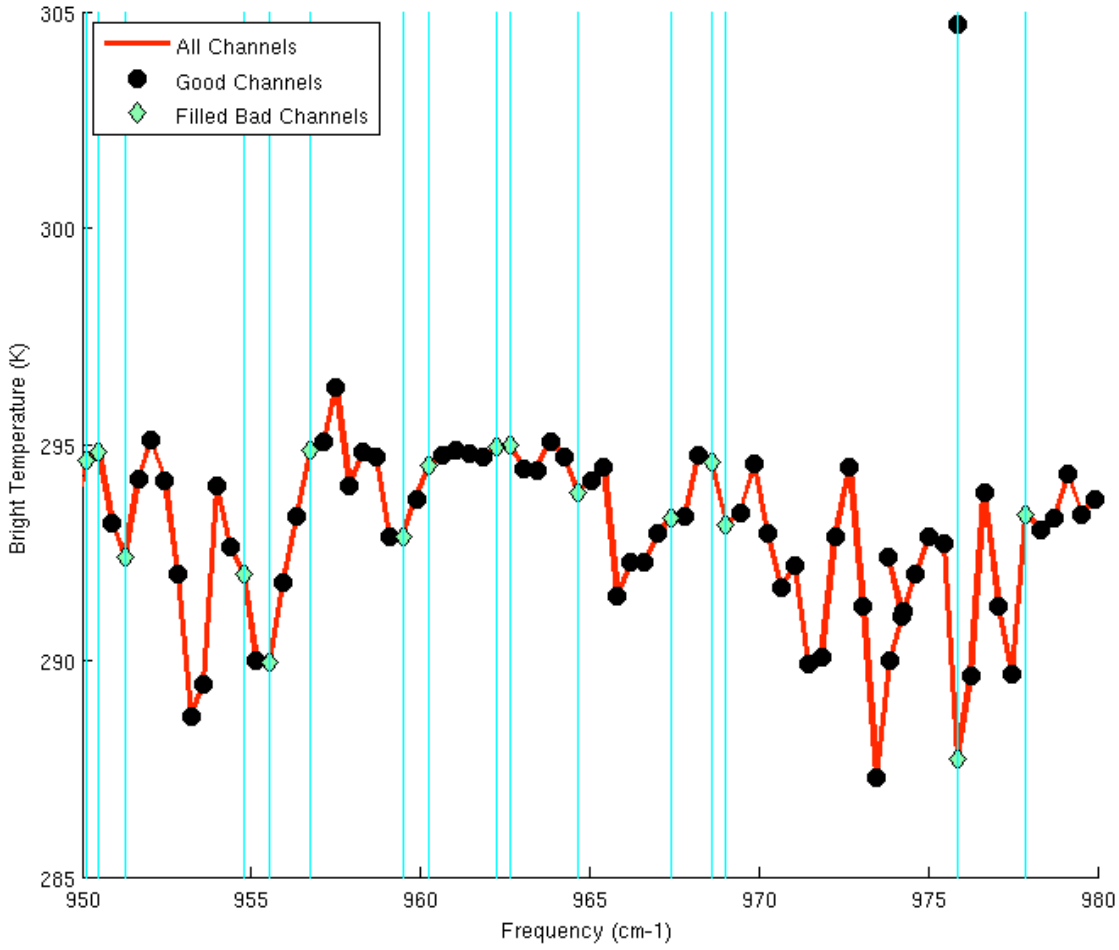
Radiance Replacement Example

- **This range of frequencies is the worst case over the entire focal plane—it has an unusual concentration of noisy channels**



Resampling

Resampling

- **The cleaned-up spectra can be resampled to a fixed frequency grid (probably the nominal frequency set we now have) once the instantaneous frequency of each channel has been determined**

- **The interpolation technique now being studied is module-by-module spline interpolation**

Planned Software Changes (Summary)

- **Level 1B will be modified to calculate and store instantaneous channel frequencies**
- **Level 1B will be modified to perform the check for "replaceable" channels and store results**
- **The Level 1B output radiances will not change**
- **A new routine will be created to generate a Level 1C product**
  - ***Perform the radiance replacement ("clean")***
  - ***Optionally resample to fixed frequency grid***
- **The RTA will be modified to use the instantaneous frequencies instead of the nominal set for retrievals**

• Backup

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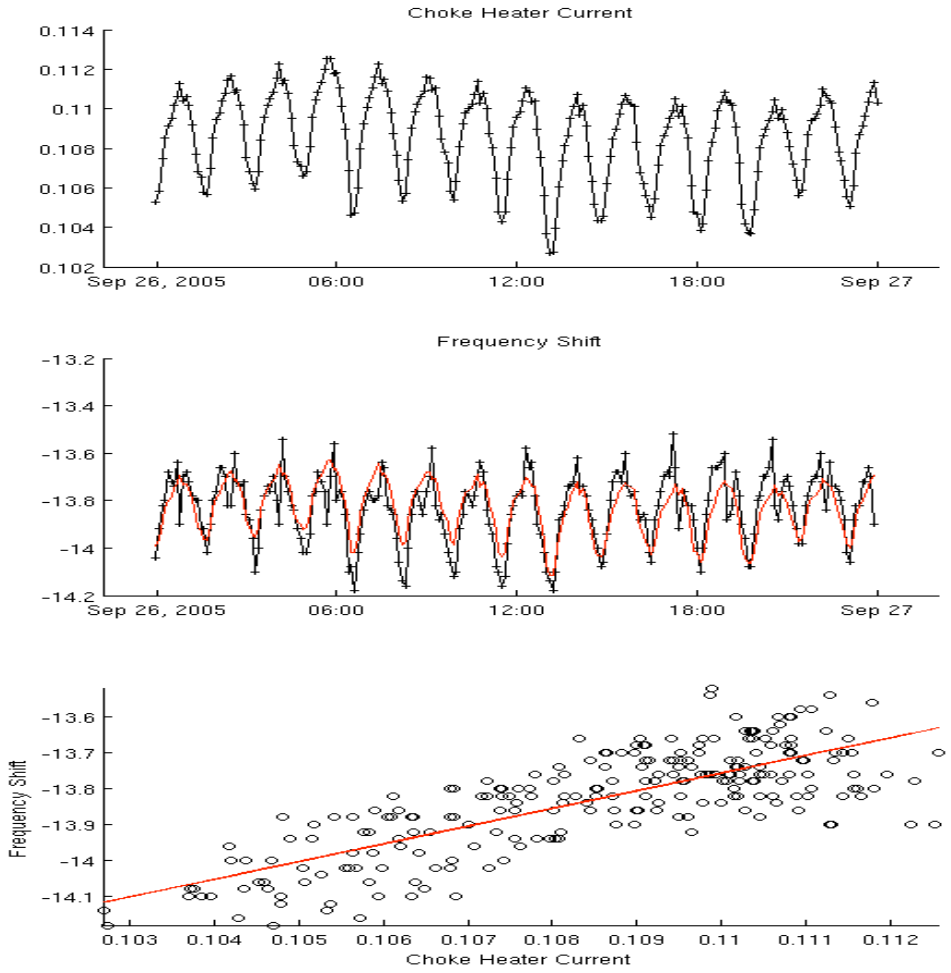
Choke Heater Current and Frequency Shift

- Choke point heater current for one day

- Black is measured frequency shift from Scott Hannon
- Red is frequency shift calculated from instantaneous value of choke point heater current

- Linear fit of choke point heater current vs. frequency shift
- Correlation is 0.78



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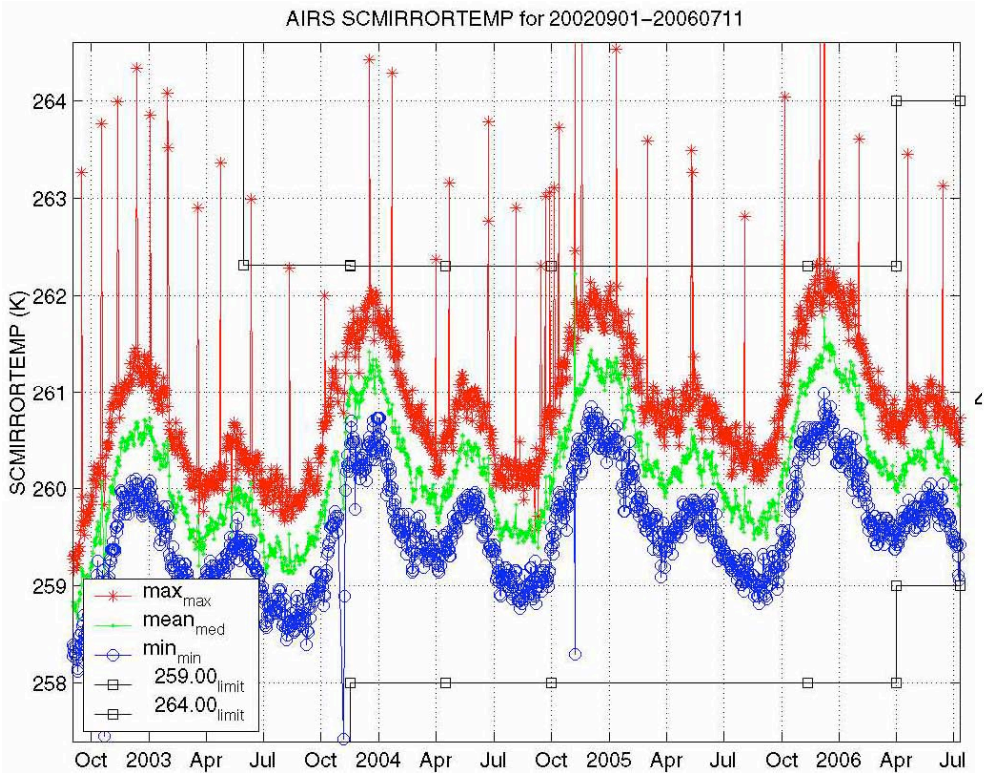
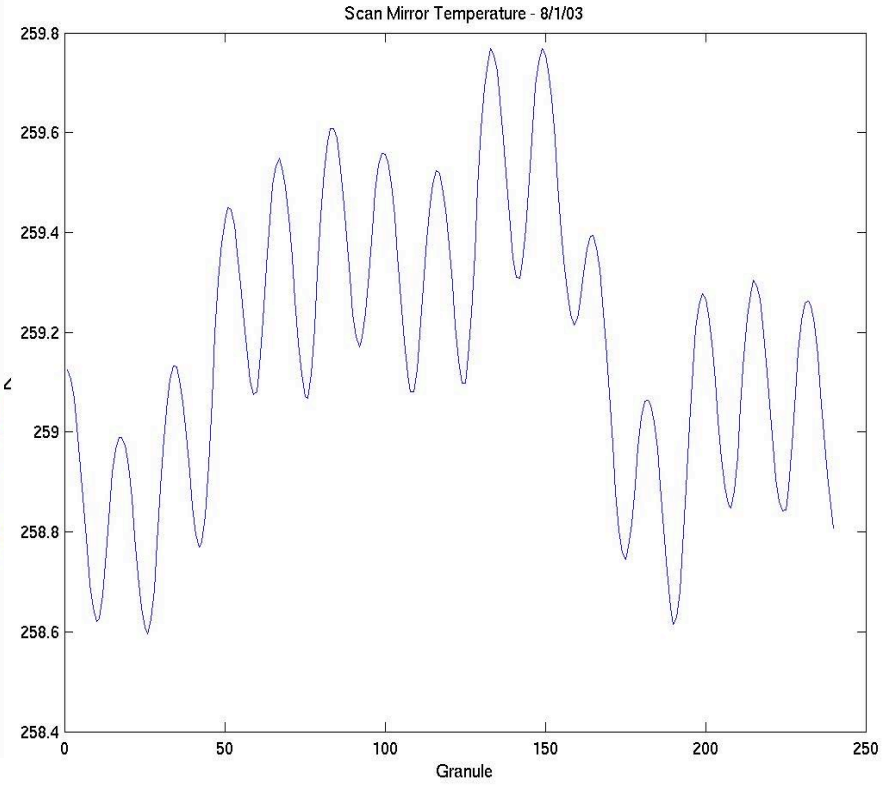
AIRS Scan Mirror Temperature Varies with Year, Season, Orbit, and S/C Maneuvers



Temperature over mission



Temperature over 1 day

- **4 K spikes due to S/C maneuvers (mirror parked on OBC), 3K seasonal variation, 1K daily variation, .6 K orbital variation, as well as a upward trend of ~0.15 K per year.**

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Effect Of Clouds On Replacement